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בעל אמצאה מכח העברה ASSIGNMENT ששמה הוא:
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(באנגלית)
A METHOD OF PRINTING ON LARGE FORMAT FLEXIBLE SUBSTRATE AND PRINTING APPARATUS (English)

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ABSTARCT OF THE INVENTION

The present invention discloses a method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry of the adjacent earlier printed image swath.

APPLICATION FOR PATENT

Title: A METHOD OF PRINTING ON LARGE FORMAT FLEXIBLE SUBSTRATE AND PRINTING APPARATUS

FIELD OF THE INVENTION

[0001] The present invention relates to the field of inkjet printing and particularly to printing on large format flexible substrates.

BACKGROUND OF THE INVENTION

[0002] Inkjet printing has gained popularity in a number of applications. One of the growing printing applications is printing of billboards, banners and point of sale displays. The ink-jet printing process involves manipulation of drops of ink ejected from an orifice or a number of orifices of a print head onto an adjacent print substrate. Paper, vinyl, textiles, fabrics, and others are examples of print substrates. An ink-jet print head consists of an array or a matrix of ink nozzles, with each nozzle selectively ejecting ink droplets. A given nozzle of the print head ejects the droplet in a predefined print position on the substrate. An assembly of the adjacently positioned on the substrate ink droplets creates a predetermined print pattern or image. Relative movement between the substrate and the print head enables substrate coverage and image creation. Each ink droplet comprises a picture element, or "pixel." Good print quality requires printing resolution higher that 600 pixel per inch. A typical pitch of an array of nozzles is however 180 or less nozzles per inch.

[0003] To produce the relative movement enabling image creation the substrate moves in one direction termed first direction, and print head moves in another direction termed second direction. The second direction is usually orthogonal to the first direction. Generally, the print head has less weight and is much smaller in size than substrate. It is convenient to move print head fast over the substrate in a type of reciprocating movement. Each successive reciprocating scan by such a print head in the second direction creates a relatively wide ink-marked strip or printed swath. The substrate is advancing simultaneously in the second direction.

[0004] In order to cover the substrate with the desired print resolution of for example 720 pixel per inch a single print head with nozzle pitch of 180 nozzles per inch has to scan in a reciprocating type of movement the print swath four times. Each scan is distant from the previous one on 1/720 of inch. The data to be printed is divided accordingly between the scans. This type of printing is called multi pass printing mode. Alternatively for printing at 720 pixels per inch resolution four print heads with nozzle pitch of 180 nozzles per inch may be organized on a common mechanical structure shifted one with respect to the other on a 1/720 of an inch. Organized in this manner print heads may print the desired image in a single pass printing mode, providing better ink coverage and creating more vivid colors. The cost of such print head structure is however too high for regular commercial use. Common structures with print heads shifted one with respect to the other on a fraction of a print head dimension (staggered) are also known in the art.

[0005] Recently inkjet print heads such as XAAR Leopard having nozzle pitch of 300 nozzles per inch and commercially available from XAAR Plc., Cambridge, UK and MAGIC having nozzle pitch of 600 nozzles per inch and commercially available from Scitex Vision Ltd., Netanya, Israel have appeared on the market. Although these print heads have nozzle pitch suitable for high quality printing the printing itself is performed in multi-pass mode. Printing in such cases is performed at full print head resolution but the amount of data to be printed is distributed between the successive print scans. Such multi pass printing method contributes to print quality and provides a better redundancy, since different nozzles participate in printing sections of the same line when scanning the substrate in a reciprocating type of movement.

[0006] In order to print an image in multi pass printing the substrate is usually advanced on a multiple of print resolution. The multiple may have a value smaller and larger than one. This relatively small incremental movement continues until the whole image is printed and requires high position accuracy, which is generally hard or even impossible to achieve by the movement of the large and flexible substrate. Errors in butting such two successive print head scan result in micro banding effects called printing artifacts. In single pass printing each successive movement of the print head in the second printing direction prints a swath of color equal in width to the print head

width. Errors in butting two successive print head wide or print structure wide swaths result in macro banding, which is also called printing artifact. In both cases the butting of two successive image swaths should be perfect, since human eye is extremely sensitive to printing artifacts caused by errors in relative positioning of the print head and substrate. (For the simplicity of explanation the term "print head" will be used for both single print head and a plurality or print heads organized on a common mechanical structure.)

[0007] There are known in the art constructions of ink jet printing machines that have a drum or a table on which the substrate is placed for printing. The accuracy of the relative movement between a rigid drum or table holding the substrate and the print head that moves on linear guides is relatively good and creates small image artifacts. These printers have however, a very large footprint, are expensive and difficult to maintain. A significant number of wide format printing applications, however is done on flexible substrate. Special printing machines termed Roll-to-Roll (R2R) printing machines, are typically used for printing on such substrates. Because the substrate has no support structures these machines have small footprint and high-speed operation. The R2R machines print on five-meter wide flexible substrates. One of the drawbacks of the Roll-to-Roll printing machines is the low accuracy of the relative movement between such a wide flexible substrate and the print head.

[0008] Figure 1 illustrates a typical Roll-to-Roll (R2R) printing machine. The machine has a substrate supply roll **100**, a substrate-collecting roll **102**, and a print head **106**. Rotation of substrate collecting roll **102** pulls substrate **108** of substrate supply roll **100** and moves it in a first printing direction indicated by arrow **110**. Print head **106** reciprocally moves in a second printing direction indicated by arrow **112**. The second printing direction is generally orthogonal to the first printing direction. Mechanism enabling print head **106** reciprocating movement in the second direction indicated by arrow **112** may be a linear motor with a guide **116**, or a metal band or linear guides with a screw drive. A regular motor (not shown) or a motor with a gear may drive substrate-collecting roll **102**. Control computer **114** controls operation of print head **106** and the printer.

[0009] Perfect swath butting, especially in multi pass printing is difficult to achieve on R2R printers. When pooled/moved flexible substrate easy stretches and deforms

and accordingly changes its dimensions. This makes small, comparable with the printing resolution incremental movement of flexible substrate with accuracy of few microns nearly impossible.

[0010] Printing of large size images on wide flexible substrates requires not only global dimensions accuracy; it requires multiple local position corrections that compensate for errors in the image printed. Errors caused by wide flexible substrate distortion. These corrections cannot be properly made by the use of the encoders. Because of substrate flexibility neither linear nor rotary encoders do not represent accurately the substrate position. There are however, no known methods of other than encoder signal derived information for local image correction.

[0011] The inventors of the present invention are also not aware of any known methods of local image correction that account for actual image on substrate position.

SUMMARY OF THE INVENTION

[0012] There is therefore a need in the industry to provide a method of printing on wide format flexible substrates free of the described above problems.

[0013] There is an additional need to improve the quality of the printed image by accurately butting successive swaths and swath filling scans of printed image in multi pass printing mode.

[0014] There is a further need in the industry to provide a low cost method of image printing capable of providing accurate local printed image position correction and reducing printing artifacts. A low cost method of image printing that accounts for actual image on substrate position.

[0015] Generally, these objectives may be achieved by a method of multi pass inkjet printing on wide format flexible substrates where printing image artifacts cased by errors (deformations) in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry of the adjacent earlier printed image swath.

[0016] Exemplary embodiments of the present invention are directed to a method and apparatus that compensates for errors in the image position caused by deformations of wide format flexible substrate movement by moving print head on the deformation (error) value and where the print head movement is performed in the same direction as the wide format flexible substrate moves. The ink jet print head movement is controlled as function of the actual printed image on substrate position. Control of the print head movement takes place during a multi pass printing process. Proper movement and positioning of the print head compensates for errors in the image position caused by wide format flexible substrate deformations and reduces or eliminates micro and macro banding effects causing printed image artifacts.

[0017] According to one exemplary embodiment the objectives of the present invention are achieved by replacing the small incremental wide format flexible substrate movement in the first direction by movement of the print head in the first direction; filling the printed swath by reciprocating scanning movement of the print head in second direction and moving the substrate in the first printing direction in swath wide steps. The magnitude of the small incremental movement or stepping of the print head in the first direction is a function of nozzle pitch (**P**) distance and printing resolution (**R**).

[0018] In accordance with this embodiment the objectives of the present invention may be achieved by a method of inkjet printing on wide format flexible substrates, comprising steps of: providing an inkjet printer having a print head, a substrate, and a control computer; moving the substrate in the first printing direction and scanning the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction, the print head further having capability of movement in the first printing direction; printing an image on the substrate by print head wide (W) swaths; filling the printed swath by reciprocating scanning movement of the print head in the second direction and stepping the print head on a desired value, which may be a multiple of print resolution (R) in the first scanning direction; moving the substrate in swath wide steps in first printing direction and where the control computer divides the movement in the first direction between said substrate

and said print head movements. (In the context of the present invention the desired value is the step value required to fill in the printed swath.)

[0019] According to another exemplary embodiment the objectives of the present invention may be achieved by advancing the wide format flexible substrate on a small incremental step and printing simultaneously with the image certain image position control marks. Image position control marks may be printed (located) on image free areas of the substrate. Alternatively image position control marks may be printed (located) within the image or on the image area. Image position control marks may be printed by visible or invisible to human eye ink. Coordinates of the image position control marks printed simultaneously with the image define the actual position of the printed image on the substrate and the substrate itself.

[0020] Image position detectors detect image position control marks coordinates and communicate these coordinates to the control computer. The substrate typically moves in first printing direction only. Print head, which generally moves in second printing direction, has additional movement capabilities in the first printing direction. The substrate movement error compensation is performed by selectively and dynamically moving the print head in the first printing direction simultaneously with the movement of the print head in the second direction. Control computer calculates the error compensation value by comparing the actual image position with the desired or target image position. Control computer generates appropriate correction signal that causes associated with it print head movement.

[0021] In accordance with this embodiment the objectives of the present invention may be achieved by a method of inkjet printing on wide format flexible substrates, comprising steps of: providing an inkjet printer having a print head, a substrate, image position detecting means, and a control computer; moving the substrate in the first printing direction and scanning the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction, the print head further having capability of movement (back and forth) in the first printing direction; printing simultaneously with the image a series of image position control marks, which define actual image on the substrate position; detecting by substrate position detecting means the control marks coordinates and providing the control marks

coordinates to the control computer; calculating the image position deviation value from the desired image position and wherein the ink jet printing is performed by correcting the image position error by moving dynamically the print head in the first direction in accordance with the image position deviation value calculated by the control computer.

[0022] The image (substrate) position error is corrected by moving the print head in the first printing direction on a step matching the error (deviation) in image position. The movement of the print head may be performed concurrently and continuously with the printed swath-filling scan.

[0023] The method of wide format inkjet printing on flexible substrate that derives the printing position based on the printed image position or on the position of digitally introduced image position control elements. Specially introduced printed marks may serve as image on substrate position control marks or elements.

[0024] Image position control marks may be printed (located) on image free areas of the substrate. Alternatively image position control marks may be printed on the areas of the substrate occupied by the image. Image position control marks may be printed by invisible or visible to the human eye ink.

[0025] The printing method of the present invention is enabled by an inkjet printing apparatus for printing on wide format flexible substrates, comprising: a substrate and a mechanism for moving the substrate, a print head and a mechanism for moving the print head, substrate position detecting means, and a control computer; the substrate moving mechanism moves the substrate in the first printing direction and the print head moving mechanism scans the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction; the print head further has a mechanism capable of moving it dynamically in the first printing direction (back and forth); the print head prints simultaneously an image and a series of image position control marks, coordinates of the image position control marks provide information on actual image position; the image position detecting means, detect the image position control marks coordinates and communicate the coordinates to the control computer; the control computer calculates the deviation of the actual

substrate position from the desired (target) substrate position, and whereby the inkjet printing is performed by correcting the image (substrate) position error along the second printing direction by moving the print head in the first printing direction in accordance with the image position deviation value .

[0026] An inkjet printing apparatus for printing on wide format flexible substrates where image position control marks may be printed by ink invisible or visible to human eyes.

[0027] The movement of the print head in the first printing direction on a value matching the image position deviation value compensates for the image (substrate) position error. Linear motors, regular screw drives, metal belts and other movement providing mechanisms or means are among means that may be used to move the print head.

[0028] An inkjet printing apparatus for printing on wide format flexible substrates where image position detection means are one of a group of photodiode, quadrant detector, solar element, CCD, or video camera.

[0029] An inkjet printing apparatus for printing on wide format flexible substrates where a control computer processes the image position deviation value describing the deviation of the actual printed image swath position from the desired (target) image swath position and generates a signal for moving the print head to a corrected scanning position along the second direction.

[0030] The advantage of the method is that it reduces the swaths macro and micro banding effects and adapts the geometry of the image to the actual position of the previous swath reducing the undesired visual effects (printing artifacts) caused by deformations in substrate size during substrate movement.

[0031] A further advantage of the method is that it does not make use of auxiliary substrate supports such as drum, table, endless metal bands or precisely formed surface reducing by this the manufacturing cost of the printing apparatus.

[0032] It is an additional advantage of the method disclosed that the printing position information is derived from the previously printed image position without the use of costly auxiliary image position monitoring means.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] The foregoing and other objects, features and advantages of the invention will be apparent from the more particular description of the exemplary embodiments of the invention, as illustrated in the accompanying drawings in which like reference numbers refer to the same parts throughout the different figures. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

[0034] Figure 1 is a schematic representation of a simplified prior art roll-to-roll inkjet printer;

[0035] Figures 2A and 2B are schematic illustration of an inkjet printer and a swath of an image printed by prior art multi pass printing method;

[0036] Figures 3 is schematic illustration of additional prior art multi pass image printing methods;

[0037] Figures 4A, 4B and 4C are schematic illustrations of an inkjet printer and an image printed by a multi pass printing method in accordance with one of the exemplary embodiments of the present invention;

[0038] Figures 5A and 5B are schematic illustrations of an inkjet printer and an image printed by a multi pass printing method in accordance with another exemplary embodiment of the present invention;

[0039] Figure 6 is a simplified flow chart of image on substrate position control marks placement decision making algorithm;

[0040] Figure 7 is an illustration of an additional exemplary embodiment of micro and macro banding (printing artifacts) reduction in accordance with the present invention. .

DETAILED DESCRIPTION OF THE INVENTION

[0041] The principles and execution of a method according to the present invention, and the operation and properties of an ink jet printing apparatus enabling the printing method may be understood with reference to the drawings and the accompanying description of non-limiting, exemplary embodiments.

[0042] Reference is now made to Figures 2A and 2B which are schematic illustrations of a prior art printer and a prior art multi pass printing method. Print head **120** is printing an image consisting of a number of swaths and in particular print swath of the image bounded by lines of rectangle **122**. Print head nozzle pitch **P** is lower than the required print resolution **R** and in order to fill print swath bounded by lines of rectangle **122** the printing is performed in a multi pass mode. For the simplicity of explanation the printing resolution **R** is equal in both first and second directions. Substrate **108** is advanced in the first direction indicated by arrow **110.** When print head **120** scans in the second direction indicated by arrow **124** each of print head **120** nozzles **126** prints respective line shown as separate square pixels **130a**. At the end of the scan substrate **108** is incrementally advanced in the first direction (first printing direction) indicated by arrow **110**, print head **120** moves back (reciprocating type of movement) in the direction indicated by arrow **146** (Fig. 2B) and each of the nozzles **126** prints respective print line shown as separate square pixels **130b**. The process continues until the swath bounded by lines of rectangle **122** is filled in. (The previous scan is shown in lines and characters having lower density.)

[0043] As illustrated in Fig. 2B the incremental advance of substrate **108** having large dimensions and being flexible is not equal along print head scan path. When pulled or moved by other means, wide size flexible substrate **108** stretches or skews and undergoes other types of distortions. These stretches and skews create visually disturbing micro banding effects (printing artifacts) shown in Figure 2B. (The printed image should have homogeneous structure and be free form visible banding effects or

artifacts.) Other numerals on Figures 2A and 2B indicate: **136** and **138** are motors that provide movement to substrate-collecting roll **102**, and print head **120** respectively; **140** is a linear guide on which print head **120** travels (scans) back and forth; **122'** designates lines of rectangle that bounds print swath printed by print head **120** when it moves back (reciprocating type of movement) in the direction indicated by arrow **146**.

[0044] Figures 2A and 2B illustrate a certain type of printed swath filling pattern in a multi pass printing mode. Some additional prior art technique for printed swath filling patterns in a multi pass printing mode is illustrated in Figure 3. Figure 3 shows a possible multi pass printing method with a print head **132** having nozzles **134** pitch **P** equal to the printing resolution **R**. Two passes are required to fill-in printed swath bounded by lines **150**. The data to be printed may be equally distributed between the passes. Such multi pass printing method contributes to print quality and provides a higher redundancy level, since different nozzles participate in printing the same line when scanning the substrate in a reciprocating type of movement. The swath width and swath filling rate were introduced for exemplary purposes only and other ratios are possible.

[0045] Present invention discloses a method and an apparatus for ink jet printing on wide format flexible substrates that reduces visually disturbing micro banding errors caused by deformations, stretches and skews of the wide format flexible substrate. Figure 4A is an illustration of an inkjet printer constructed in accordance with one of the embodiments of the present invention and a swath of a printed image printed by the printer of the present invention. Not like in the existing prior art inkjet printers print head **120** of the inkjet printing apparatus of the present invention in addition to the capability of moving in the second direction indicated by arrow **124** has capability of moving in the first direction (back and forth) indicated by arrow **170**. Direction **170** is generally parallel with first direction indicated by arrow **110**. (Figure 4 shows direction **170** of print head movement as a vertical one. It is necessary to mention that the method is applicable to any print head position and movement direction.)

[0046] Mechanism (means) **174** enabling print head **120** movement in the first direction indicated by arrow **170** may be a linear motor, a metal band or a linear guide with a drive screw. The particular shown mechanism **174** is a regular drive screw

with a motor. Print head moving mechanism **174** moves print head **120** in the direction indicated by arrow **124** from one edge of substrate **108** to the second edge of substrate **108**. In course of this movement print head **120** ejects ink droplets and prints a swath bounded by lines of rectangle **176**. Each nozzle **126** of print head **120** prints a line of pixels **178a**. Print head pitch **P** is lower than the required print resolution **R** and in order to fill-in print swath bounded by lines of rectangle **176** the printing is performed in multi pass mode. In accordance with the present invention for the purpose of filling in printed swath **176** movement of print head **120** in the first direction replaces the small incremental advance of flexible substrate **108**. Figure 4B shows printing of the next swath filling scan. When print head makes the next scan moving in the direction of arrow **146** it prints pixels **178b**. For printing pixel(s) **178b** print head position was changed as indicated on scale **210** on two digit. (Scale **210** is introduced for illustrative purposes only.) Print head **120** movement in the direction indicated by arrow **170** is parallel to the movement of image (substrate) **108** in the first (printing) direction **110** and is relatively small, as compared to the magnitude of substrate **108** movement. Accordingly the print head moving mechanism may have relatively small amplitude of movement and use small size and low cost encoders.

[0047] Figure 4C shows next swath filling print head **120** scanning pass. Four passes are required to fill-in the particular printed swath (the last pass is not shown). The information to be printed is distributed between the swaths. The multi pass swath filling pattern has been shown for exemplary purposes only. Other swath filling patterns are possible.

[0048] Following completion of swath filling wide flexible substrate **108** advances on swath width (**W**) in the first direction and print head moving mechanism **174** returns print head **120** to the initial position. Other movement sequences where the print head is returned into the initial position for example, in course of the beginning of the next swath filling process, are possible. The distribution of the movement in the first direction between print head **120** and wide flexible substrate **108** significantly reduces micro banding effects and associated with them printing artifacts. Control computer **114** controls the movement of print head **120** and the split of movements in the first direction between print head **120** and substrate **108**.

[0049] In accordance with another exemplary embodiment shown in Figure 5A inkjet printing apparatus of the present invention in addition to print head **120** moving means **174** has image position detecting means **180**. Image position detection means **180** may be located along the second printing direction. Generally, image position detection means **180** should be of extended form to cover the whole width of printing substrate **108**. Alternatively image position detection means **180** may be positioned at predefined locations over substrate **108**. Their position may be fixed or adjustable as appropriate for a particular machine design. Image position detection means **180** include a source of illumination and a detector. The source of illumination may be an incandescent lamp, a LED or a laser diode operating in visible or non-visible range of spectrum. The detector may be a photodiode, a quadrant detector a CCD, or a video camera type detector. Control computer **114** controls operation of all units of the printer.

[0050] For printing, substrate-moving mechanism moves substrate **108** in first printing direction indicated by arrow **110**. Print head moving mechanism moves print head **120** in the direction indicated by arrow **124** from one edge of substrate **108** to the second edge of substrate **108**. In course of this movement print head **120** ejects ink droplets and prints a swath bounded by lines of rectangle **190**. Print head pitch **P** is lower than the required print resolution **R** and in order to fill print swath bounded by lines of rectangle **194** the printing is performed in multi pass mode. In accordance with the present invention concurrently to printing a print swath of an image print head **120** prints in predefined positions image on substrate position control marks **200**.

[0051] Following each successive swath print, wide flexible substrate **108** advances on the required distance in the first direction. This advance of wide flexible substrate **108** is not an accurate one, since deformations introduced into wide flexible substrate are not homogeneous across the width of substrate. In order to compensate for deficiencies of substrate moving mechanism, resulting in micro banding, image on substrate position detecting means **180** detect and measure the coordinates of image position control marks **200**.

[0052] Substrate position detecting means **180** communicate the coordinates of image position control marks **200** to control computer **114**. Image on substrate position

control marks **200** are indicators of the actual image on substrate position (and the position of substrate itself). Control computer **114** uses the coordinates of image position control marks **200** to calculate the deviation of the actual image or pixel position from the target or desired image position. The desired (target) image position in this particular configuration is a function of print head pitch and printed image resolution. Control computer **114** calculates the required correction movement of print head **120** with respect to the previously printed swath.

[0053] In accordance with the present invention in course of print head **120** movement in the second direction indicated by arrow **146** print head moving mechanism **174** performs continuous (dynamic) corrective movement of print head **120** in the direction indicated by arrow **170**. This movement is generally parallel to first printing direction **110**. The corrective movement of print head **120** compensates for deformations and an error caused by wide format flexible substrate movement and reduces visible micro banding effects. Scale **210** is introduced for illustrative purposes only. It shows that when print head makes the next scan moving in the direction of arrow **146** and printing pixels **192b** its position was adjusted on one digit at the beginning of the scan and on two digits at the end of the scan. Allover print head movement was three digits.

[0054] Generally, the method of multi pass inkjet printing on wide format flexible substrates adapts the geometry and position of the next printed swath to the geometry and position of the adjacent earlier printed image swath.

[0055] As illustrated in figures 2B and 5B wide flexible substrates do not deform in a homogeneous way along their width or length and some areas of the printed image may have deformations larger than the other. In order to correct the micro and macro printed swath butting errors caused by the non-homogeneous deformation of wide format flexible substrate along the printed swath image position control marks should be located along and across a printed swath enabling dynamic print head position correction. Image position control marks **200** may have any shape suitable for machine detection and convenient for deriving based on the image on substrate position detector readings the actual new position of flexible substrate **108**. The size

of image on substrate position control marks **200** is selected to enable reliable position detection without affecting image quality or content.

[0056] Figure 5B illustrates an exemplary placement and form of image position control marks **200** along and across printed swath **190** and **190'**. When position control marks **200** are located along and across printed swath i.e., within the printed image itself their size and color should be selected in way that does not created undesired visual effects. Alternatively image position control marks **200** may be printed by invisible to human eye ink.

[0057] Digital image analysis precedes or is made concurrently with the swath printing process. The purpose of the analysis is to define proper position locations of image position control marks **200** along and across printed swath **190**. Figure 6 shows a simplified image position control marks **200** position locations algorithm. Initially, (step **230**) the digital image to be printed is partitioned into printed swaths and strips of image pertaining to the same swath are defined. Printing is usually performed in four process colors cyan, magenta, yellow and black (CMYK). The proportion of each of the process colors within each of the swaths is different and at step **232** ink coverage or content for a particular printed swath is calculated for each ink. Image position control marks **204** are preferably printed by a color (ink) that has largest coverage (proportion) in a particular swath. This ink is selected at step **234**. Further to this image on substrate position control marks printed when print head moves in the direction indicated by arrow **124** are preferably placed in places that will be overprinted by ink of the same color when print head **120** will move in the direction indicated by arrow **146**. In order to find suitable control marks places within the image at step **238** swath with highest ink content is further analyzed for sections having clusters of inked pixels of sufficient size for marks placement.

[0058] Distribution of image on substrate position control marks along and across printed swath in a way that enables relatively smooth continuous print head position control takes place at step **240**. The processed swath is printed simultaneously with image on substrate position control marks at step **242**. The process continues in a similar way for the next swath.

[0059] Distribution of image positions control marks along and across printed swath in a way that enables relatively smooth continuous print head position control within a single color (ink) may not always be possible. Highlight print areas may have not enough dense clusters for proper control marks positioning. In such extreme cases image on substrate position control marks may be placed in more than one printing color (ink).

[0060] Alternatively image position control marks may be printed by ink invisible to human eye, but easy detectable by image position detection means. Such marks may be printed in any location on the substrate and not special image processing is required. Printing control marks by ink invisible to human eyes requires however, an additional print head and increases the cost of the machine. Such ink may be a clear ink Crystal UGE-0513 commercially available from Sun Chemicals (Sunjet), Fort Lee, NJ U.S.A.

[0061] Figure 7 shows an additional exemplary embodiment that provides another way of improvement of the printing accuracy and banding effects reduction. A line type mark **256** may be printed as the first line on image free area providing a reference for image on substrate position detectors operation. First printed swath is aligned to this line. Location of image on substrate position detectors along the scanning path enables simultaneous reading of a large number of image on substrate control marks coordinates and provides means for making a practically smooth print head correction movement.

[0062] Although the exemplary embodiments illustrate so-called micro banding artifacts correction, or correction of artifacts between the successive scans within the same print swath, the method is applicable to corrections of the macro banding artifacts or artifacts between two relatively wide printed swaths. The method is also applicable to detection and compensation of missing lines and pixels providing a higher degree of redundancy in multi pass printing without using additional print heads or spare nozzles.

[0063] Prints printed by the disclosed printer produce images of significantly improved quality, as compared to existing printers. They do not exhibit micro banding

effects and have reduced macro-banding effects. The width of printed substrate may be further increased without damaging print quality.

[0064] The above disclosure is intended as merely exemplary, and not to limit the scope of the invention, which is to be determined by reference to the appended claims.

What is claimed is:

1. A method of multi pass inkjet printing on wide format flexible substrates, comprising steps of:

   a. providing an inkjet printer having a print head, a substrate, and a control computer;

   b. moving said substrate in first printing direction and scanning said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction,

      i) said print head further having capability of movement in said first printing direction (back and forth);

   c. printing an image on said substrate by print head wide (W) swaths;

   d. filling said printed swath by reciprocating scanning movement of said print head in second direction and stepping said print head on a desired value in first direction;

   e. moving said substrate in said first printing direction in swath wide steps, and

wherein said control computer divides the movement in the first direction between said substrate and said print head movements.

2. A method of ink jet printing on wide format flexible substrates, as in claim 1 wherein the step of print head movement in said first direction is derived from the relation between print head width (W), nozzle pitch (P) and print resolution (R).

3. A method of inkjet printing on wide format flexible substrates, comprising steps of:

a. providing an inkjet printer having a print head, a substrate, image position detecting means, and a control computer;

b. moving said substrate in first printing direction and scanning said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction;

i) said print head further having capability of movement in said first printing direction (back and forth);

c. printing simultaneously with an image a series of image position control marks, said control marks defining actual image position on said substrate;

d. detecting by said image position detecting means said control marks coordinates and providing said control marks coordinates to said control computer;

e. calculating the image position deviation value of said actual image position from the desired (target) image position, and

wherein said inkjet printing is performed by correcting said image position error by moving said print head dynamically in said first printing direction in accordance with said deviation value.

4. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks printing is performed by ink visible to human eyes.

5. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks are printing by ink invisible to human eyes.

6. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks location is selected within the image area.

7. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of defining the direction of print head movement in said first direction is derived from actual image position.

8. An ink jet printing apparatus for printing on wide format flexible substrates, comprising:

   a. a substrate and a mechanism for moving said substrate, a print head and a mechanism for moving said print head, image position detecting means, and a control computer;

   b. said substrate moving mechanism moves said substrate in first printing direction and said print head moving mechanism scans said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction;

   c. said print head further has a mechanism capable of moving it dynamically in said first printing direction (back and forth);

   d. said print head prints simultaneously an image and a series of image position control marks, coordinates of said marks provide information on actual image position on said substrate;

e. said image on substrate position detecting means, detect said image on substrate position control marks coordinates defining actual image on substrate position and communicate said coordinates to said control computer;

f. said control computer calculates the deviation of said actual image position from the desired (target) image position, and

whereby said inkjet printing is performed by correcting said substrate position error by moving said print head in said first printing direction in accordance with said image position deviation value.

9. An ink jet printing apparatus for printing on wide format flexible substrates, as in claim 8 and where substrate detection means are one of a group of photodiode, quadrant detector, CCD and video camera.

10. A method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by moving print head on said deviation value (back and forth) and where said print head movement is performed in the same direction as said wide format flexible substrate moves.

11. A method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry of the adjacent earlier printed image swath.

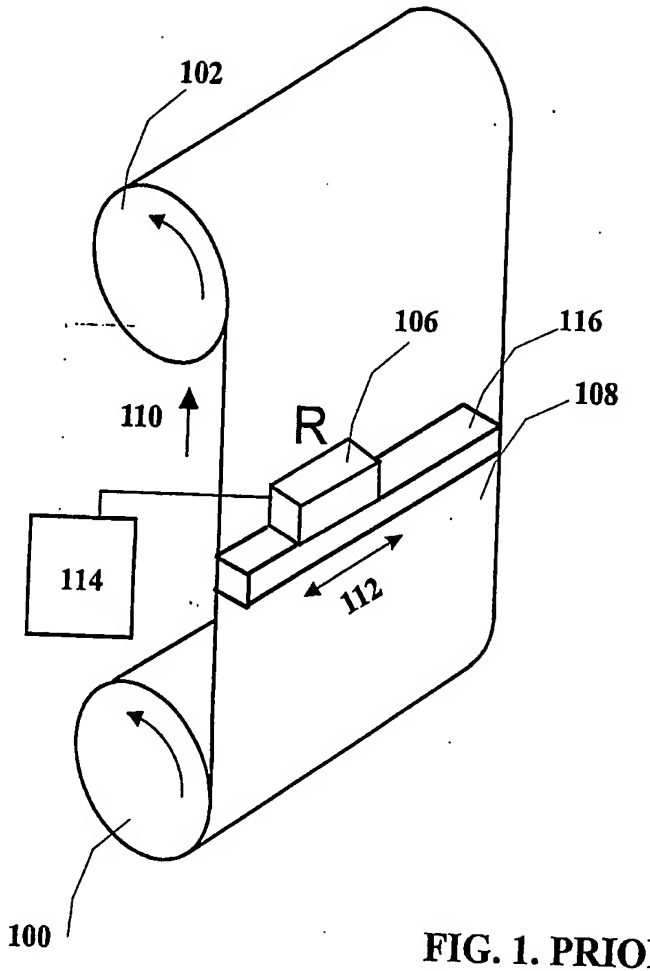

FIG. 1. PRIOR ART.

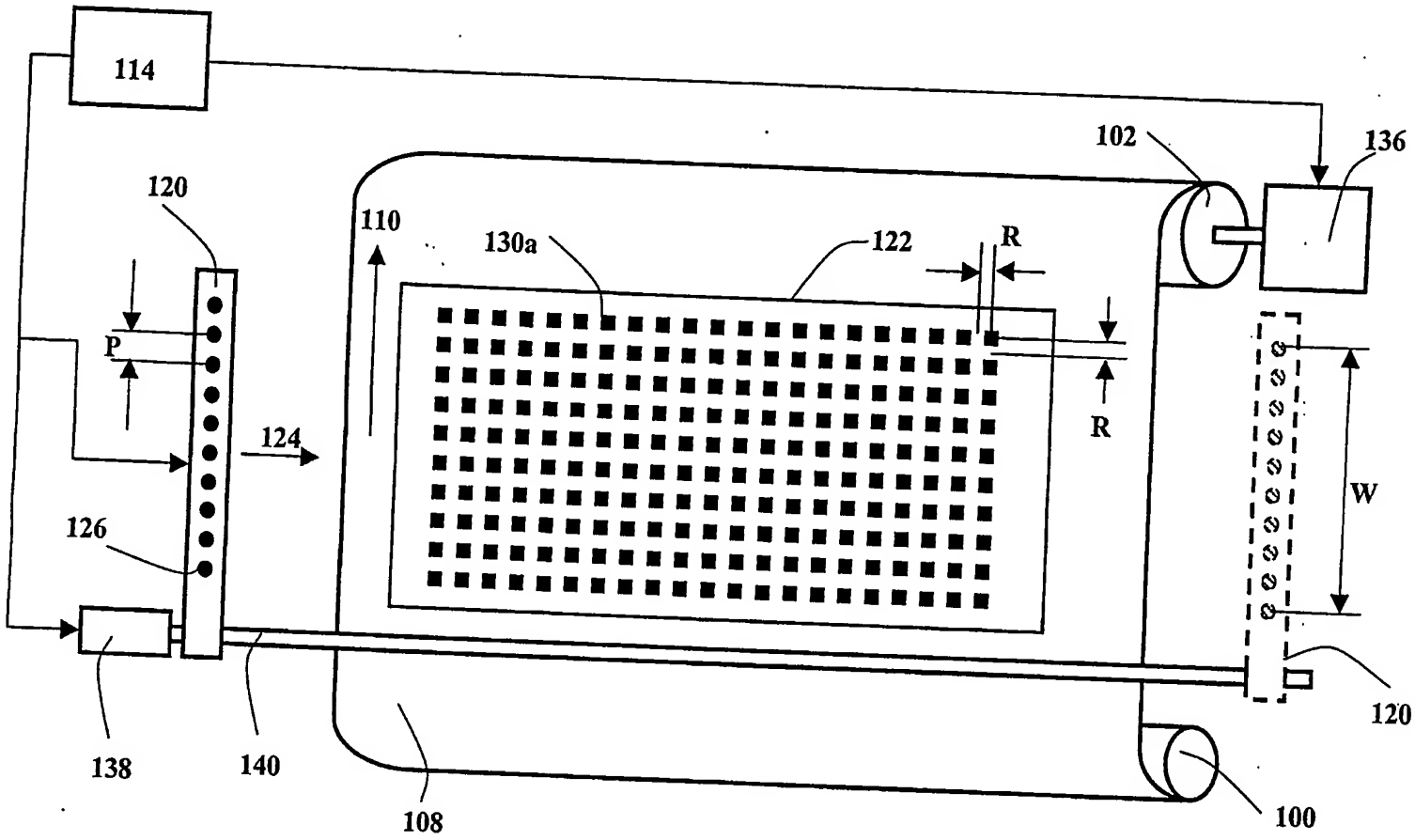

FIG. 2A. PRIOR ART

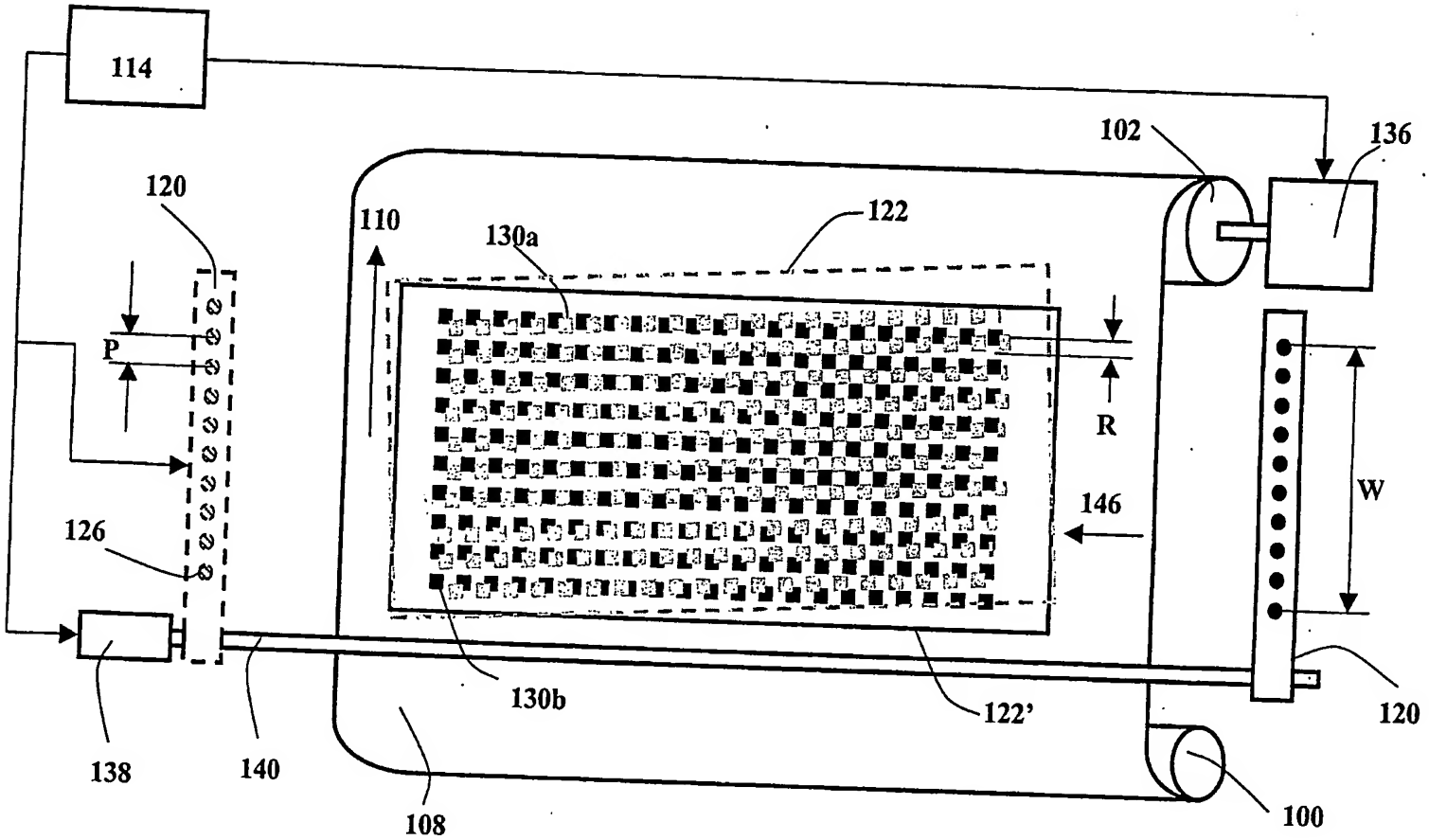

FIG. 2B. PRIOR ART

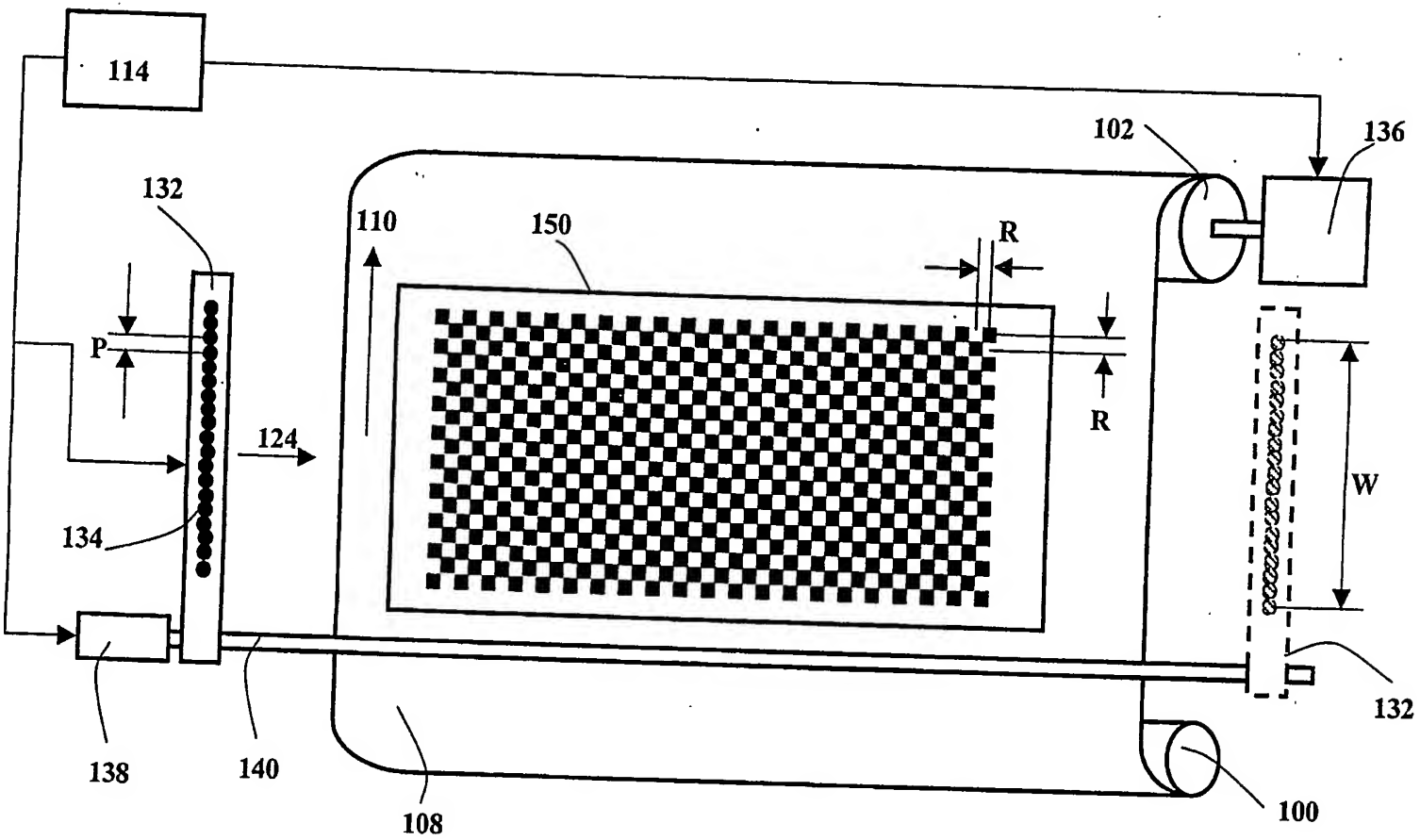

FIG. 3.

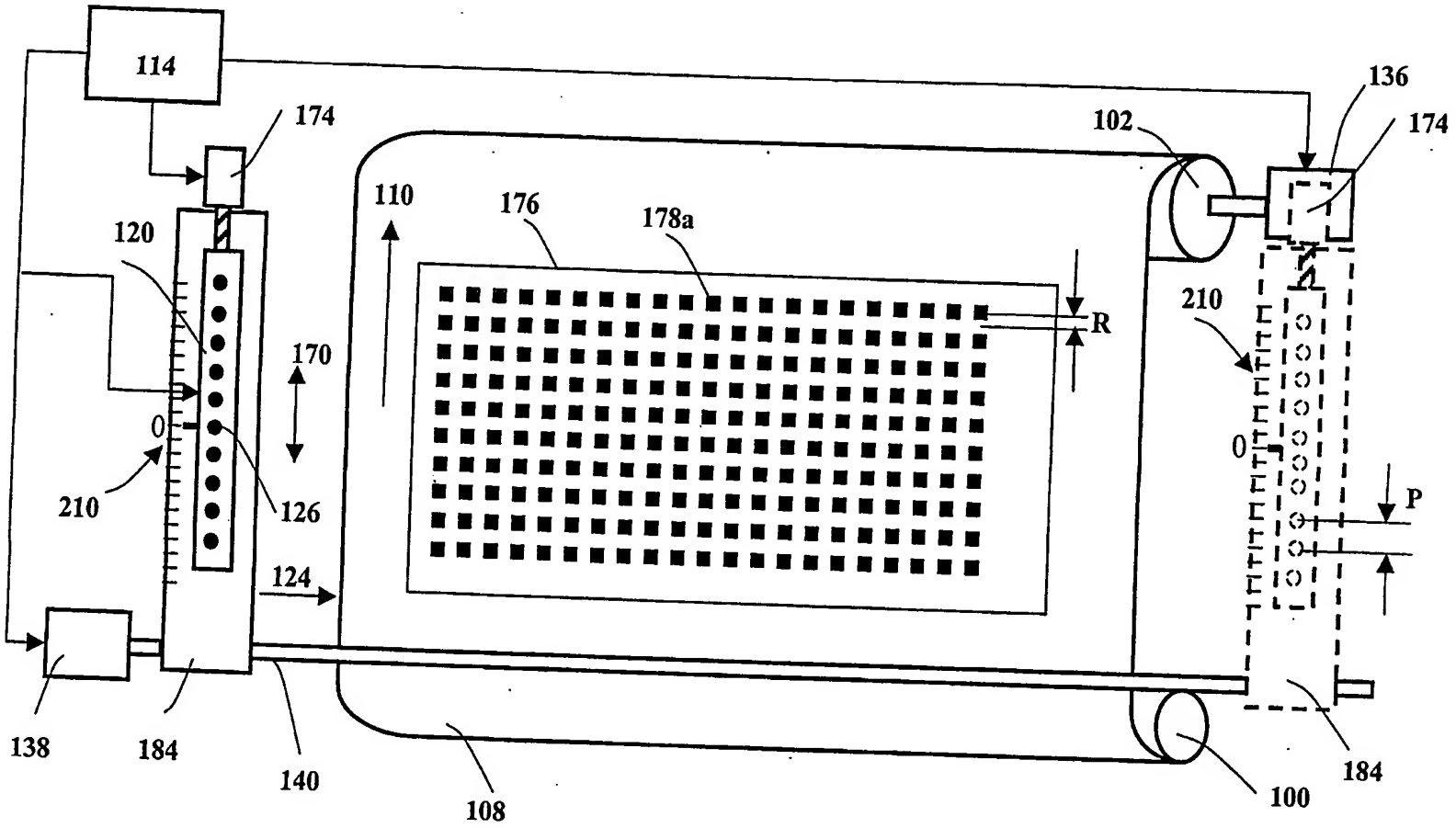
114
174
120
110
176
178a
102
136
174
R
210
170
0
210
126
124
P
0
138
184
140
108
100
184

FIG. 4A.

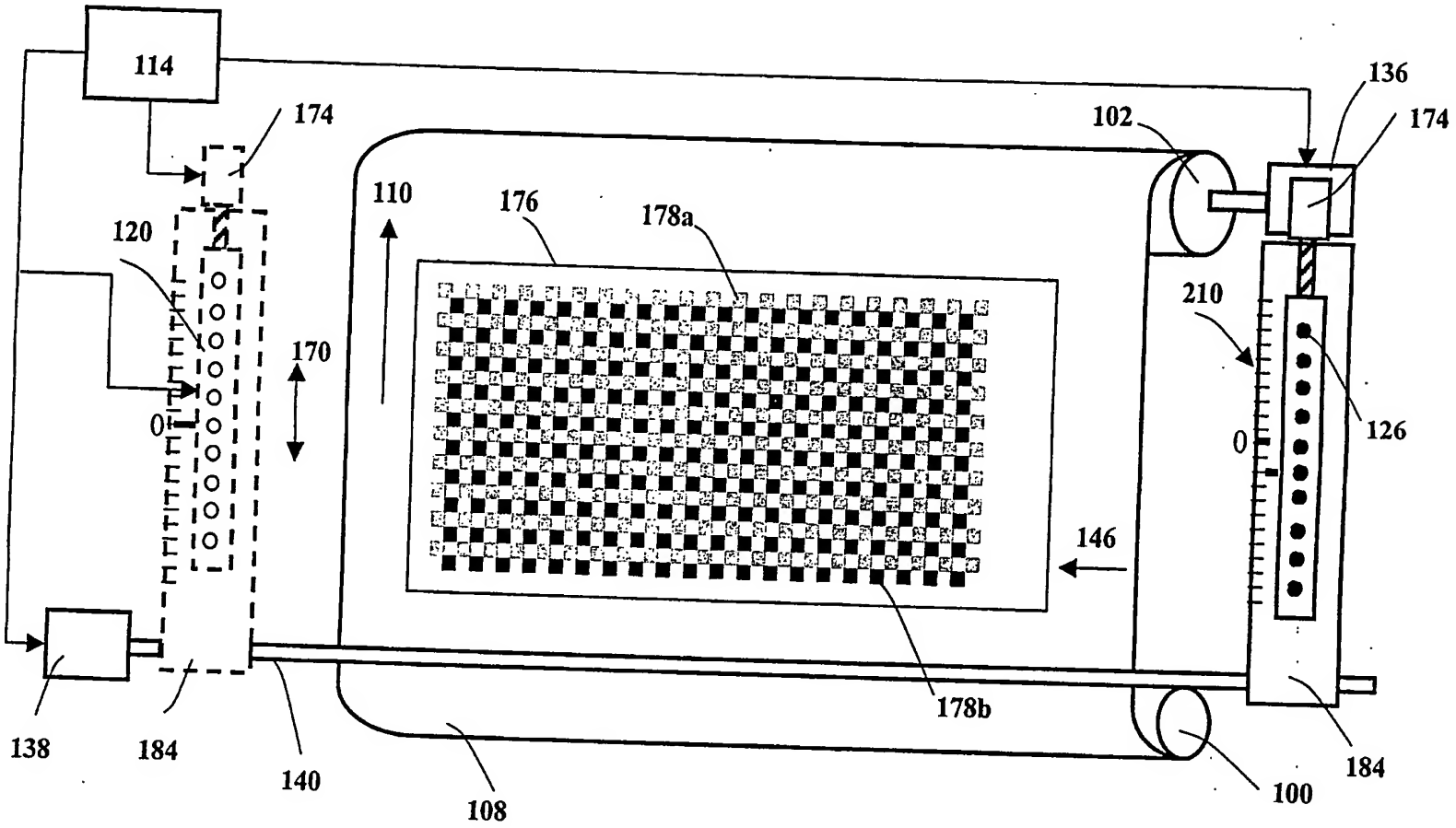
114
174
120
0
170
110
176
178a
102
136
174
210
126
0
146
178b
138
184
140
108
100
184

FIG. 4B.

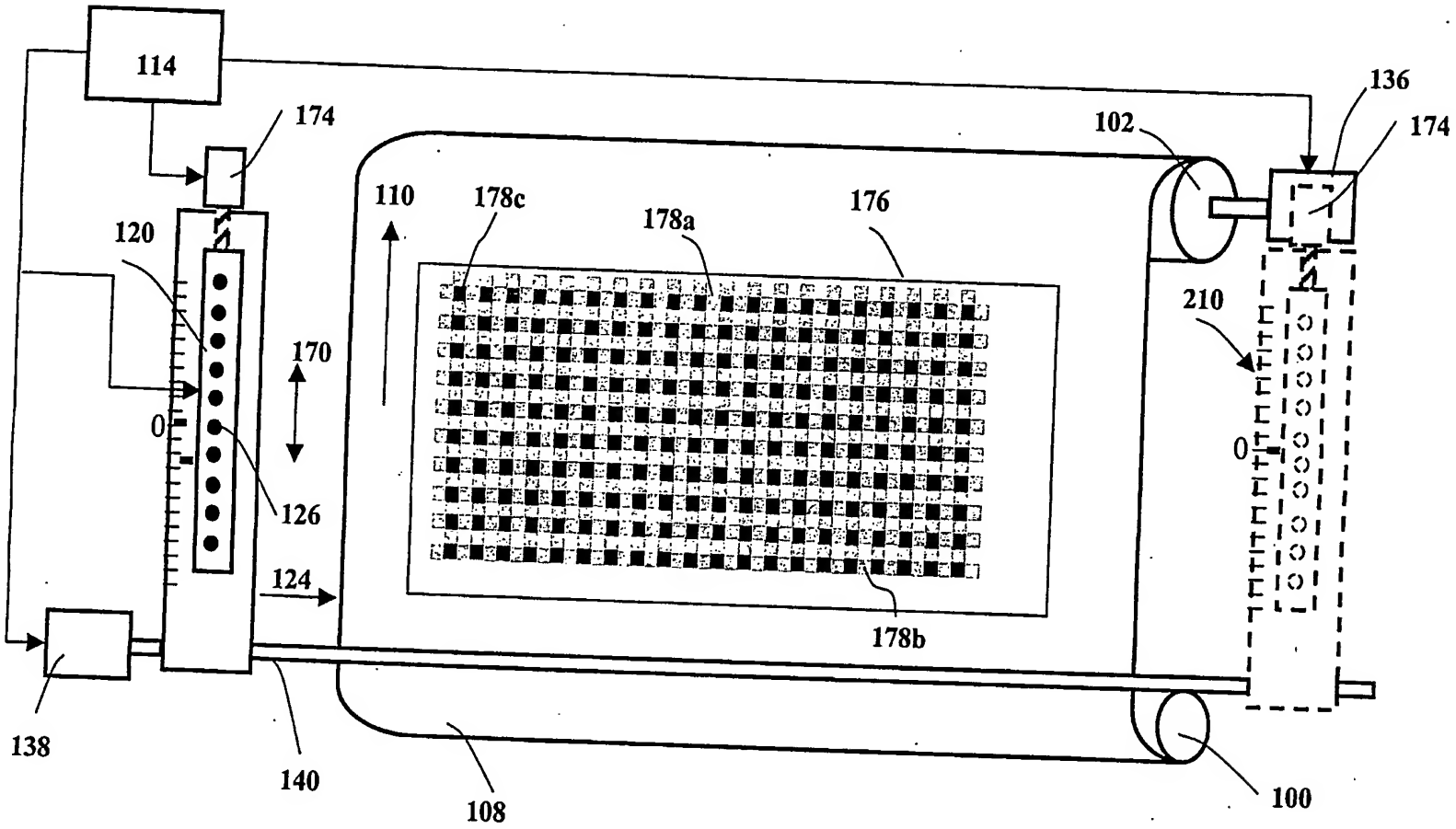
114
174
120
0
126
170
110
178c
178a
176
102
136
174
210
0
124
178b
138
140
108
100

FIG. 4C.

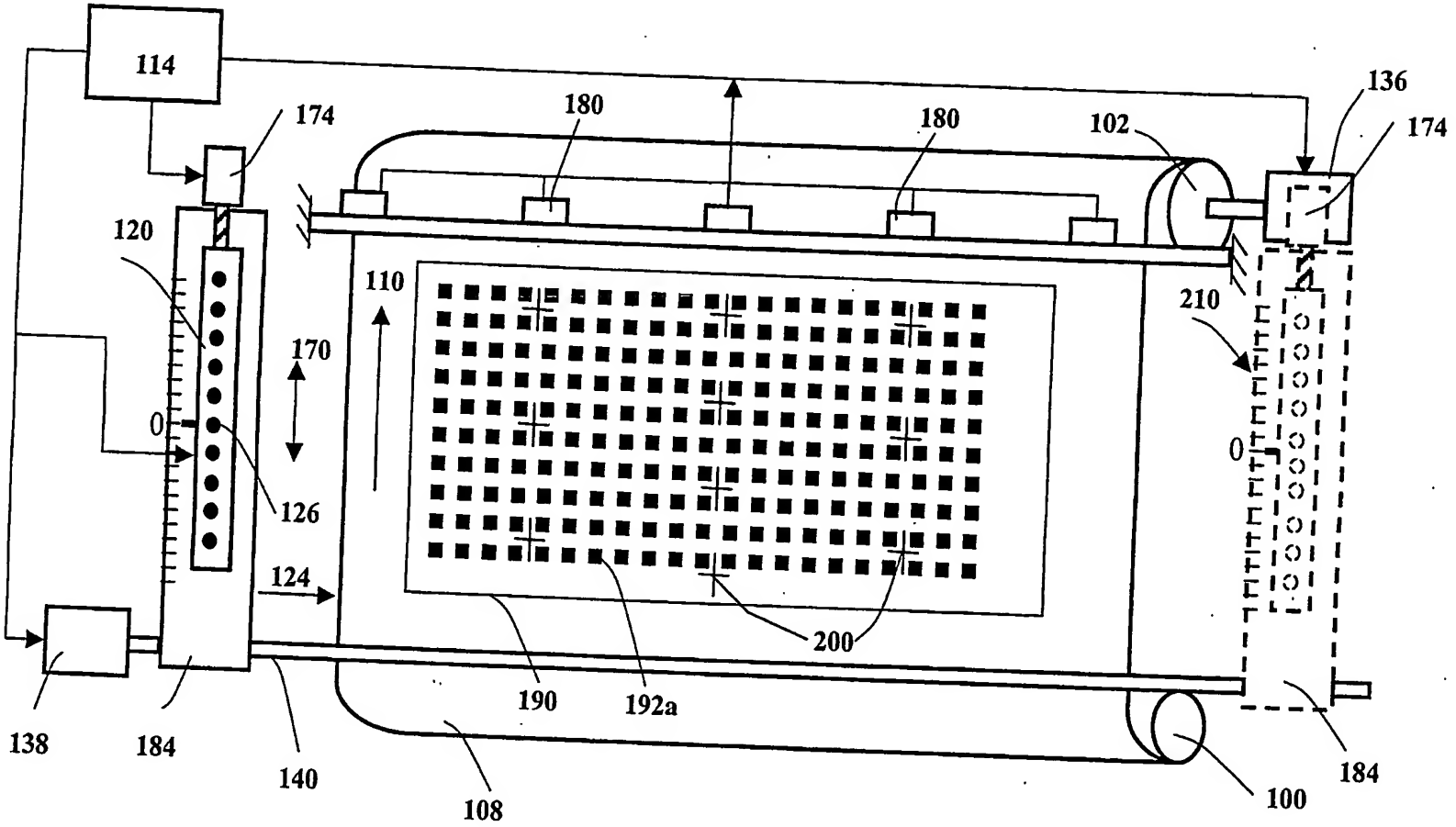
114
174
180
180
102
136
174
120
110
170
0
126
124
210
0
200
190
192a
138
184
140
108
100
184

FIG. 5A.

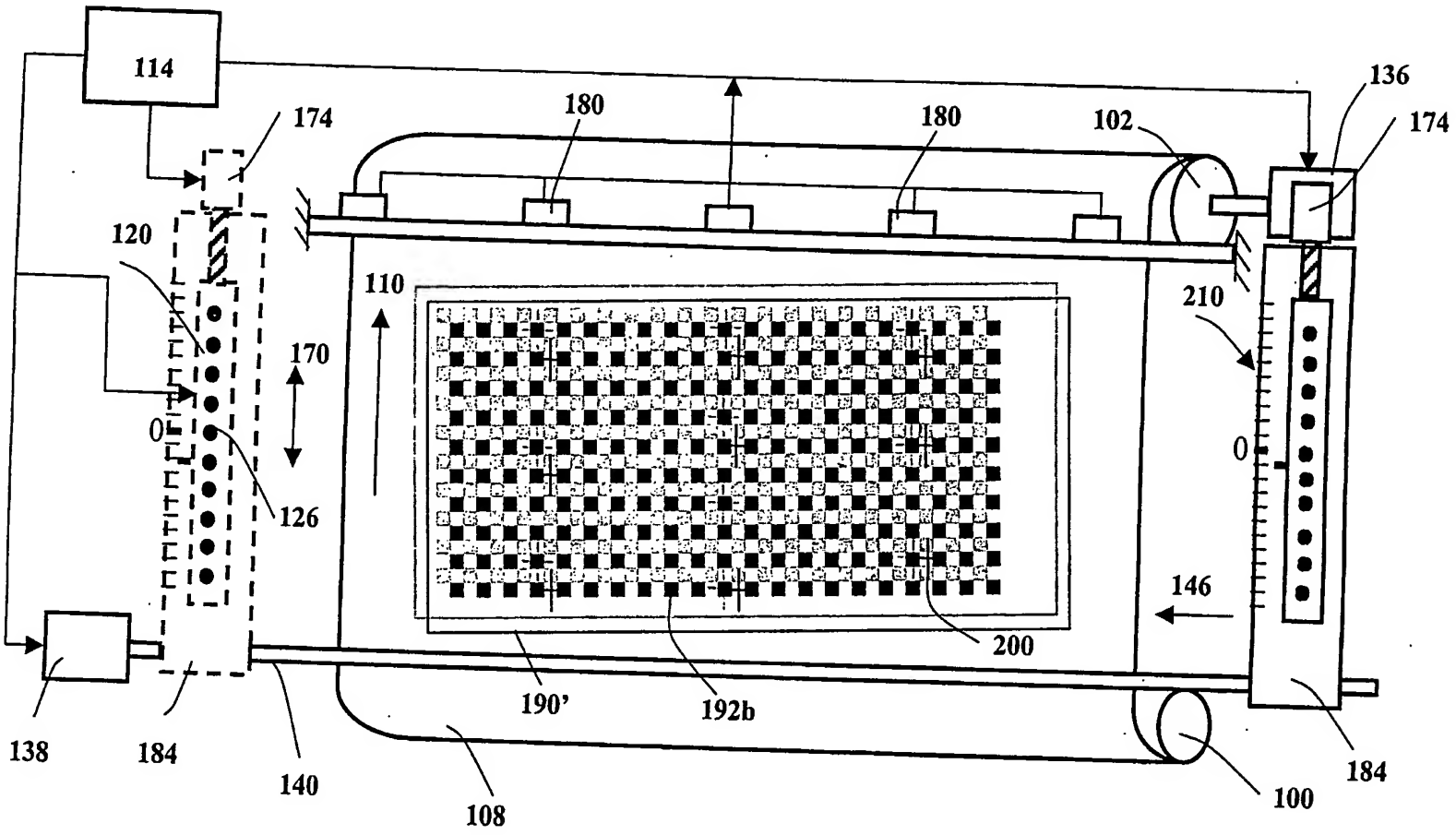
114
174
180
180
102
136
174
120
110
210
170
0
0
126
146
200
190'
192b
138
184
140
108
100
184

FIG. 5B.

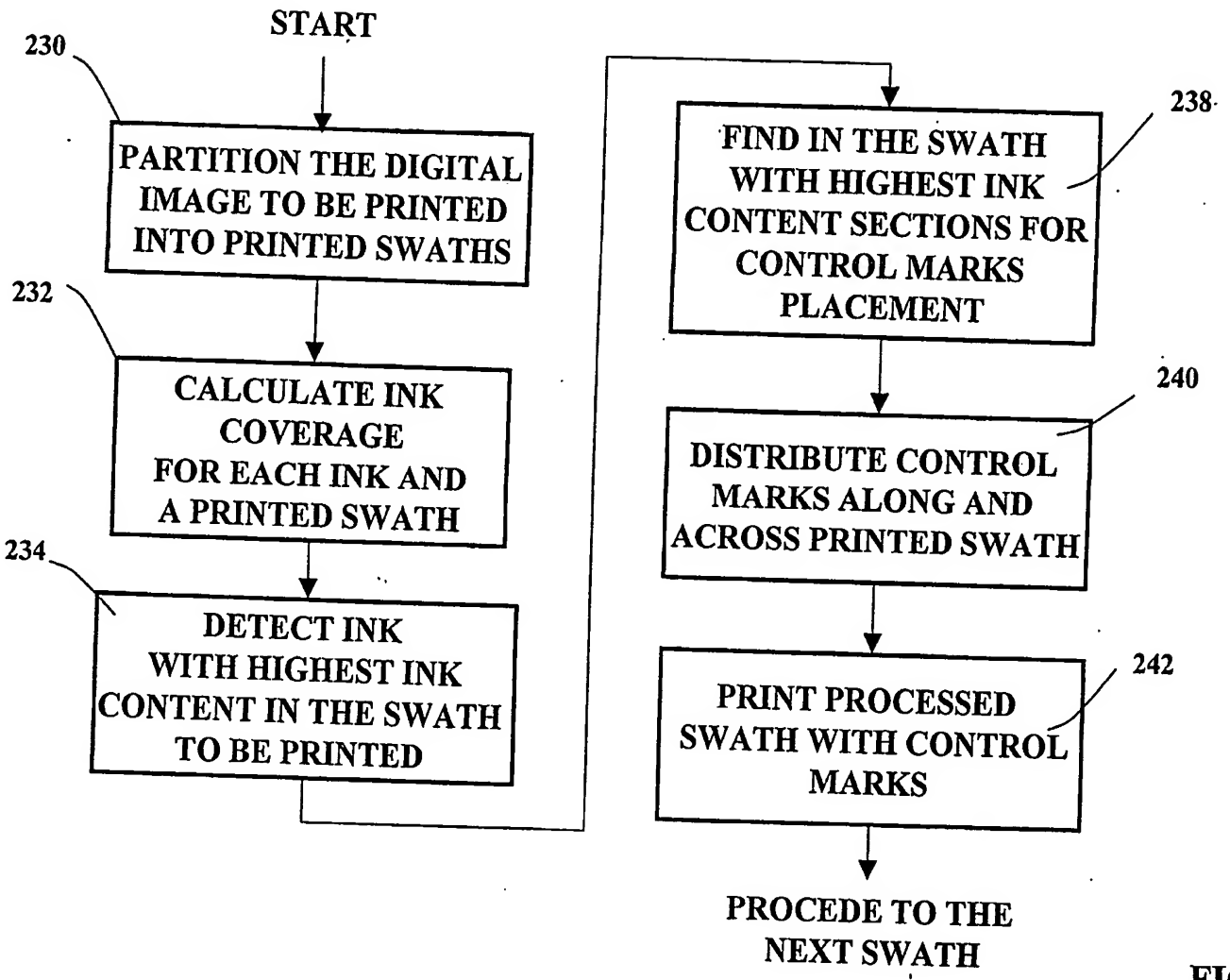
START
230
PARTITION THE DIGITAL IMAGE TO BE PRINTED INTO PRINTED SWATHS
232
CALCULATE INK COVERAGE FOR EACH INK AND A PRINTED SWATH
234
DETECT INK WITH HIGHEST INK CONTENT IN THE SWATH TO BE PRINTED
238
FIND IN THE SWATH WITH HIGHEST INK CONTENT SECTIONS FOR CONTROL MARKS PLACEMENT
240
DISTRIBUTE CONTROL MARKS ALONG AND ACROSS PRINTED SWATH
242
PRINT PROCESSED SWATH WITH CONTROL MARKS
PROCEDE TO THE NEXT SWATH

FIG. 6.

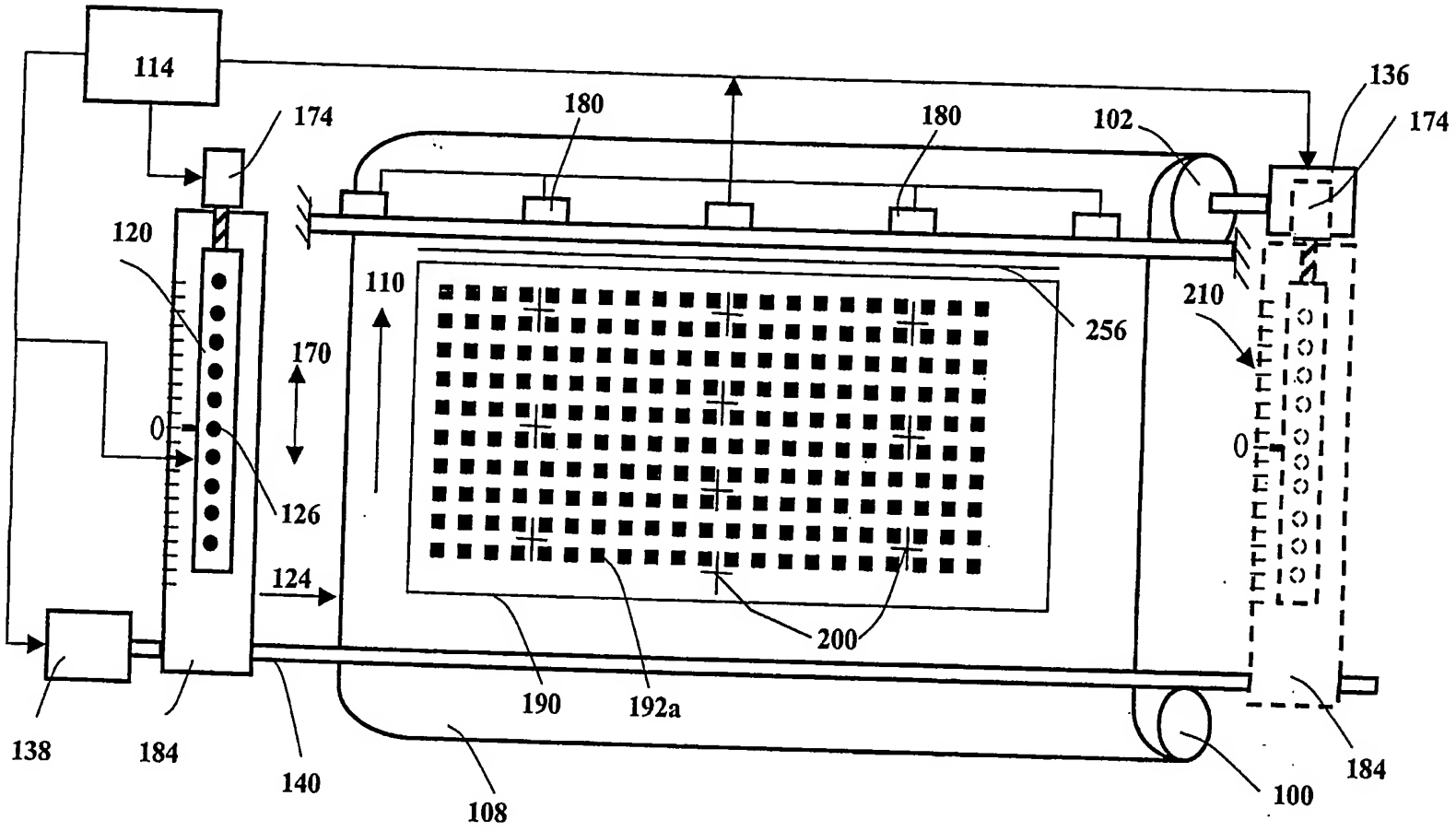
114
174
180
180
102
136
174
120
110
256
210
170
0
126
0
124
200
190
192a
138
184
140
108
100
184

FIG. 7.